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Assessing Cotton Yield Loss to Hail Damage in Southern Arizona

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Hail storms are unpredictable and can cause economic losses each year in all cotton-growing areas of Arizona (Figure 1). Most growers who finance all or a portion of their production are required to purchase hail insurance, especially in regions with a high frequency of hail storms. About 70% of Arizona cotton growers purchase hail insurance due to the occurrence of heavy thunderstorms which can be accompanied by hail during the summer monsoon season. Information on assessment of cotton yield losses caused by hail storms is important for making replanting and other management decisions. Additionally, understanding insurance adjustment and cotton growth dynamics after hail damage helps growers protect their interests. This article will familiarize growers with estimating hail-induced yield loss in cotton at different growth stages and management options following a hail storm.

Cotton yield loss due to hail damage depends mainly on the crop's growth stage when a hail storm occurs and the storm's intensity. In hail loss adjustment, V and R are used to represent vegetative and reproductive growth stages, respectively (USDA-FCIC, 2003; NCIS, 2006). For example,

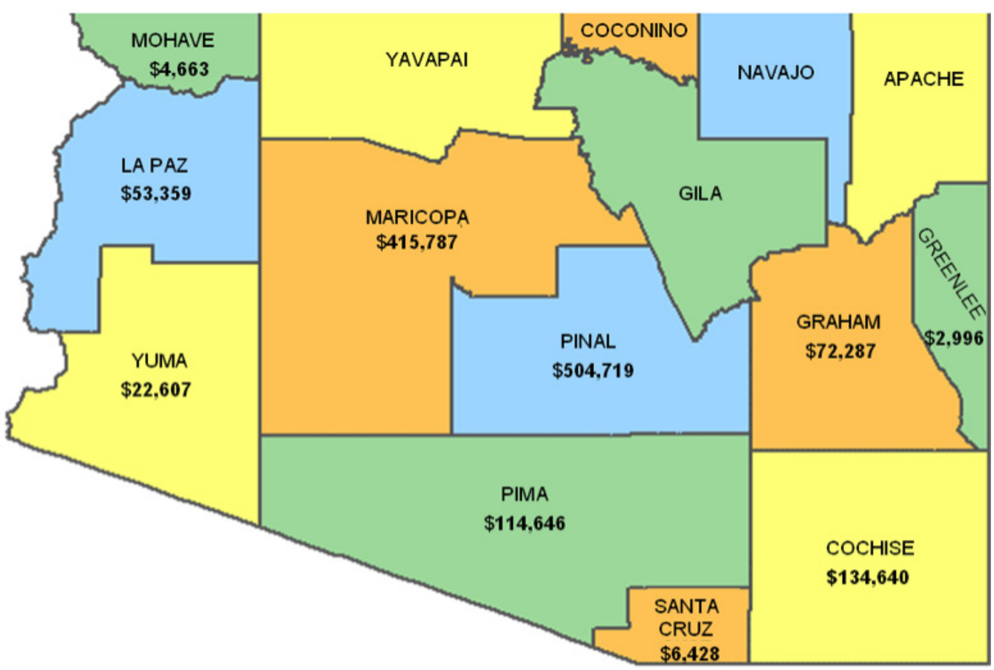

Figure 1. Average yearly cotton loss to hail damage in Arizona counties from 1948 to 2009. The actual dollar value in each year was not adjusted to show current dollar value. Data were provided by National Crop Insurance Services (Mark Zarnstorff and Bryan Baggett, Personal Communication).

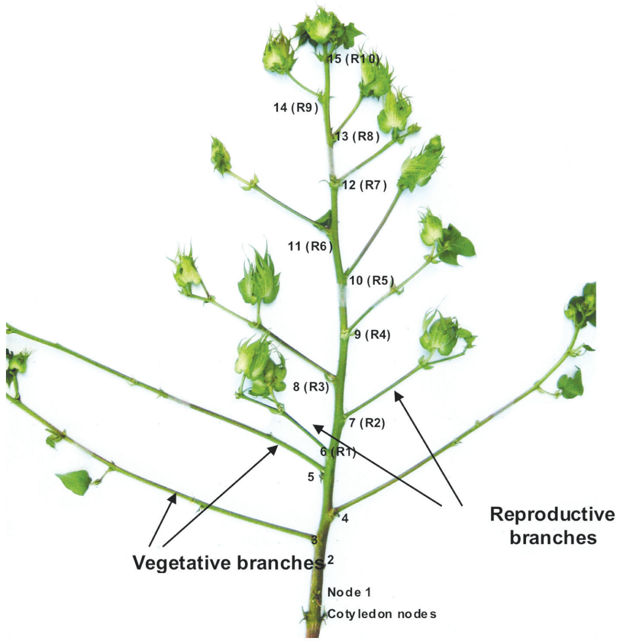

Figure 2. Cotton vegetative branches (branches on node 1 to 5 are V1 to V5) and fruiting branches (R1 to R10 are shown).

V5 represents the stage where the fifth vegetative internode has elongated by 0.5 inches or more (the cotyledon node is considered node zero), and R10 represents the stage where plants have 9 fruiting branches and the internode above the 9th fruiting branch has elongated by 0.5 inches or more (Figure 2). Growth stage is identified at the time of loss through field sampling. A crop is deemed to have reached a specific growth stage when 50% of the plants are at or beyond the given phase of development. All yield loss estimates are calculated from plants in representative 10-foot row-length samples in the damaged field. The number of samples required to obtain an accurate estimate of cotton yield loss depends on the variation in intensity of the hail storm damage and the crop growth stage in the field.

Assessing hail damage during vegetative growth

A step-by-step procedure to estimate cotton yield loss due to hail damage was developed by USDA-FCIC (2003) and NCIS (2006). First, the total number of cotton plants and the number of plants that are completely destroyed are recorded for each 10-foot row-length sample. For example, assume that hail damage occurred in a field and a representative sample area had a density of 28 plants per 10 foot length of a 38-inch bed (equivalent to a density of 36,590 plants/A) at growth stage V5. If 18 plants in the 10-foot row-length were destroyed, the yield loss due to stand reduction is estimated as 10% according to Table 1.

Table 1. Cotton percent yield loss due to stand loss at vegetative growth stage *

Density** (Plant/A)	Original plants/10-foot bed	Total plants destroyed in 10-foot bed																			
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
52272	40											3	4	5	7	11	18	30	54	76	100
47045	36				2	2	2	3	3	3	4	5	7	11	18	30	54	76	100		
41818	32			2	2	3	3	3	4	5	7	11	16	30	54	76	100				
36590	28		2	2	2	3	3	4	6	10	17	28	52	75	100						
31363	24	1	2	2	3	3	5	8	14	25	48	72	100								
26136	20	1	2	3	4	8	14	25	48	72	100										
20909	16	2	2	5	11	21	44	70	100												
15682	12	3	8	18	40	67	100														
10454	8	7	28	59	100																

* Adapted from Cotton Loss Instructions (Crop Hail) (NCIS, 2006).
** The density is calculated based on the commonly used 38-inch bed width in the Central Arizona

Table 2. Cotton percent yield loss due to different cut-off (i.e., stem removal) positions at different growth stages*.

Node #	Growth stage **	Cut-off position ***						
		CC	C1	C2	C3	C4	C5	C6
1	V1	25	15					
2	V2	30	25	15				
3	V3	40	30	20	10			
4	V4	45	35	25	15	10		
5	V5	**50**	40	**30**	20	**15**	10	
6	V6	55	45	35	25	20	25	10

* The table is adapted from USDA Cotton Loss Adjustment Standards Handbook (USDA-FCIC, 2003) on page 69 on **www.rma.usda.gov/fcic/2003/cop/lossadjustmentstandards.pdf.**

** Vx represents the stage when the x^{th} vegetative internode has elongated by 0.5 inches or more.

*** Cx means cotton plants were cut off above node 'x'. For example, CC means cotton plants were cut off above cotyledon node and C3 means cotton plants were cut off above node 3.

In the next step, each of the remaining plants in the 10-foot row-length sample is examined for hail damage. The cotton yield loss due to plant cutoff is assessed in this step using the information in Table 2. Plant cutoff or C in Table 2 is defined as stem removal above a node. For example, CC means cotton plants were cut off above cotyledon node and C2 refers to cotton plants cut off above node 2. Continuing with the above example, if we assume that of the 10 un-destroyed plants, there were 4 intact plants (0% yield loss for the 4 plants), 2 plants were cut off at CC (50% loss for the 2 plants), 1 plant was cut off at C2 (30% loss for the plant), and 3 plants were cut off at C4 (15% loss for the 3 plants). The average percent yield loss due to plant cutoff is then calculated as: (0+0+0+0+50+50+30+15+15+15)/10 = 17.5%. The total yield loss for this sample area is 27.5%, the sum of the yield loss due to destroyed plants (10%) and that due to plant cutoff (17.5%).

If the damage occurs at an early growth stage when replanting is still possible, growers are faced with a decision to either keep the reduced crop population or replant the field. In this case, cotton yield loss due to the reduced crop population and number of partially damaged plants (if the field is kept) should be compared with replanting costs and the yield loss due to a later planting date (if the field is replanted). This choice should be made based on a cost-benefit analysis to minimize growers' loss. Information on cotton yield responses is available for most areas so that growers can estimate their yield loss due to both reduced plant populations and later planting dates. Figure 3 shows the effects of planting density and planting date on cotton yield in Maricopa, AZ (Galadima et al., 2003; Silvertooth et al., 1998). Since other variables, such as cotton varieties, location, soil type, and management practices, also affect the relationship between planting density/date and crop yield, growers are encouraged to consult with local extension agents and specialists to determine which option to take.

Assessing hail damage during reproductive growth

Normally replanting is not an option if hail damage occurs during reproductive growth. Thus growers should compare the expected income from the estimated crop yield after hail damage, with the anticipated costs of managing and harvesting the crop. If the income from the remaining

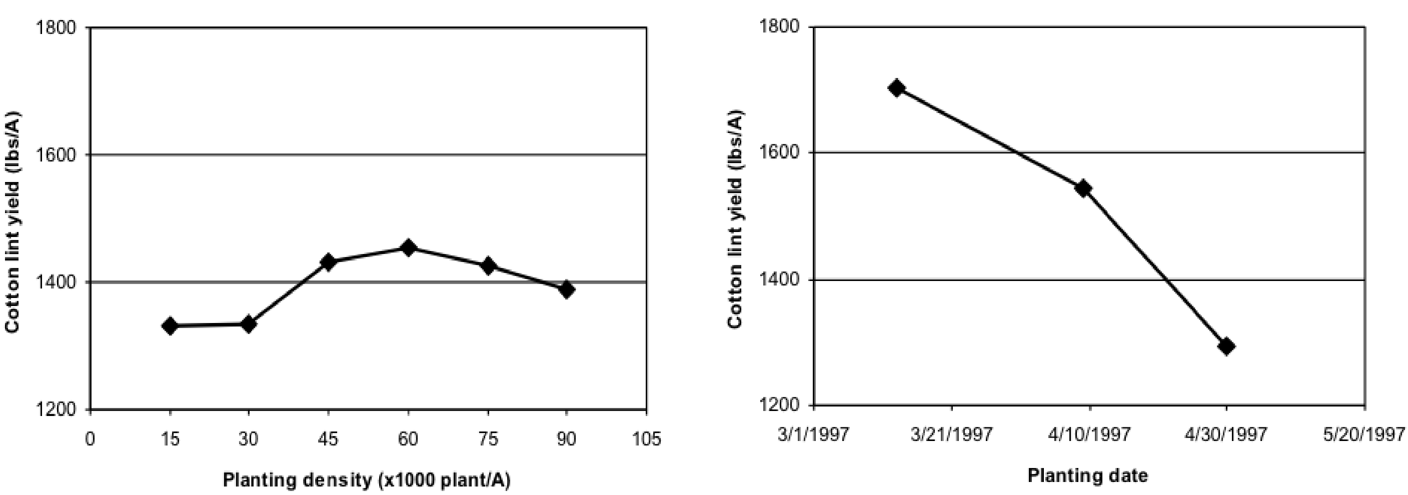

Figure 3. Cotton yield response to planting density (left) and planting date (right) in Maricopa, Arizona. Response of cotton yield to both planting density and planting date is average of three varieties (Galadima et al., 2003; Silvertooth et al., 1998).

Figure 4. Cotton apical growing point and fruiting branch damage from an August 2010 hail damage incident in the Central Arizona.

crop is not enough to cover management costs, the crop should be terminated. During reproductive growth, hail can destroy apical growing points, fruiting branches, and/or bolls (Figure 4). This makes estimating yield loss due to hail damage during reproductive growth more complicated. The first step is to estimate percent yield reduction caused by stand loss (plants totally destroyed) and cutoff at different positions (the main-stem apical growing point is lost). In the second step, the percent yield loss caused by damage to fruiting branches is estimated for plants with intact main-stem apical growing points. Finally, percent yield loss due to boll and lock loss is estimated. The total yield loss is computed as the sum of all the above estimations and expressed as percent loss at the particular growth stage.

For example, assume a hail storm occurred at the R11 growth stage (when plants had 11 fruiting branches) and a representative sample had a density of 20 plants per 10 foot length of a 38-inch bed (equivalent to a density of 28,750 plants/A). Assume also that among the 20 plants, there were 10 plants with intact apical growing points (0% yield loss for the 10 plants), 3 plants were cut off at C4 (100% yield loss for the 3 plants), 4 plants were cut off at C8 (60% yield loss for the 4 plants), and 3 plants were cut off at C14 (25% yield loss for the 3 plants) (Table 3). The total yield loss due to plant cutoff in this particular sample would be the average yield loss from all 20 plants: (0+0+0+0+0+0+0+0+0+0+100+100+100+60+60+60+60+25+25+25)/20 = 30.8%.

Table 3. Cotton percent yield loss as a function of cut-off node and growth stage *.

Growth stage**	Cut-off position ***											
	CC	C1	C2	C3	C4	C6	C8	C10	C12	C914	C16	C18
R1	60	50	40	30	25	15						
R2	65	55	45	35	30	20	10					
R3	70	60	50	40	35	25	15					
R4	80	65	55	45	40	30	30	10				
R5	90	70	60	50	45	35	25	15				
R6	100	80	70	60	50	40	30	20	10			
R7	100	90	80	70	60	45	35	25	15			
R8	100	100	90	80	70	50	40	30	20	10		
R9	100	100	100	100	90	60	45	35	25	15		
R10	100	100	100	100	100	70	50	40	30	20	10	
R11	100	100	100	100	**100**	80	**60**	45	35	**25**	15	
R12	100	100	100	100	100	80	70	50	40	30	15	5

* The form is adapted from USDA Cotton Loss Adjustment Standards Handbook (USDA-FCIC, 2003) for Maricopa, Pinal, Yuma, Mojave, LaPaz, and Pima counties in Arizona. The complete form can be found on page 70 on **www.rma.usda.gov/fcic/2003/cop/lossadjustmentstandards.pdf.**

** Rx represents the stage when the x^{th} reproductive internode has elongated by 0.5 inches or more.

*** Cx means cotton plants were cut off above node 'x'. For example, a plant cut off above node 8 (C8) when cotton is at R11 stage is estimated to lose 60% of its yield, and a plant cut off above node 14 (C14) when cotton is at R11 stage is estimated to lose 25% of its yield.

Table 4. Cotton percent yield loss due to fruiting branch loss at different growth stage *.

Growth stage**	Number of fruiting branch destroyed in 10 plants									
	10	20	30	40	50	60	70	80	90	100
R1										
R2	2									
R3	2	7								
R4	2	7	11							
R5	2	7	11	15						
R6	3	7	11	15	19					
R7	3	7	11	15	19	23				
R8	3	8	12	16	20	24	28			
R9	3	8	12	16	20	24	28	32		
R10	3	8	12	16	20	24	28	33	37	
R11	3	8	12	17	21	25	29	34	38	42
R12	4	9	13	18	22	26	31	36	40	44
R12+	5	10	15	20	25	30	35	40	45	50

* The form is adapted from USDA Cotton Loss Adjustment Standards Handbook (USDA-FCIC, 2003) and for Arizona and California only. The complete form can be found on page 73 on **www.rma.usda.gov/fcic/2003/cop/lossadjustmentstandards.pdf.**

** Rx represents the stage when the x^{th} reproductive internode has elongated 0.5 inch or more.

The next step is to calculate yield loss due to fruiting branch damage. For this, the number of fruiting branches that were destroyed in the 10-foot row-length sample area is counted. If a plant was cutoff at a certain position, only the fruiting branches below the cutoff point are assessed. Continuing with the example above, if a total of 40 fruiting branches are lost from the 20 plants in the sample area, the number of fruiting branches destroyed for every 10 cotton plants is 40/20*10 = 20. The resultant yield loss due to fruiting branch loss is then estimated as 8% according to Table 4.

The number of small (less than ½ of the full size), large (larger than ½ of the full size), and mature bolls destroyed are also recorded to estimate total yield loss. If part of a large or mature boll is destroyed, the yield loss should be counted as a fraction of the whole boll. For a variety having 4 (or 5) locks per boll, every 4 (or 5) locks count as a boll. Assume that there was a total of 10 small bolls, 6 large bolls, and 0 mature bolls destroyed in the above sample area. The number of small, large, and mature bolls lost per 10 plants would be estimated as 10/20*10 = 5, 6/20*10 = 3.0, and 0/22*10 = 0, respectively. The USDA-FCIC and NCIS use a boll factor of 0.25, 0.5, and 1 for small, large, and mature bolls for the purpose of estimating yield loss due to boll damage. Therefore, the yield loss for the sample area due to boll damage would be calculated as (5*0.25) + (3.0*0.5) + 0 = 2.8%.

Therefore, the total yield loss in the example due to the hail storm at the R11 growth stage is estimated as follows:

	Yield loss due to plant cut off	30.8%
+	Yield loss due to fruiting branch damage	8.0%
+	Yield loss due to boll and lock damage	2.8%
=	Total yield loss	41.6%

Assessing hail damage after all bolls are set

If all bolls that contribute to the final yield are already set at the time of the hail storm, then the "100 Boll Count" approach should be used to estimate yield loss. In this situation, 100 consecutive bolls (small, large, and mature) that will contribute to the ultimate yield are counted at least two weeks after the hail storm so that bruised and rotten bolls can be identified. Whole, partial (counted as a fraction), destroyed, bruised, or rotten bolls within the 100 boll sample are counted to calculate percent yield loss. For example, if there were 17.5 equivalent bolls lost in a late season storm when all bolls were set, the yield loss due to the hail storm in this sample area would be 17.5%.

A hail storm at this growth stage, such as the one that occurred in many areas of Arizona in 2010, could cause significantly higher loss in defoliated cotton fields compared to non-defoliated fields where bolls are partially protected by leaves. However, due to leaf damage caused by a hail storm in non-defoliated fields, crop defoliation could be more difficult due to the fact that a smaller leaf area remains to absorb defoliants, resulting in more leaf trash in the harvested cotton.

Other management considerations

Growers may need to extend the growing season and invest more in water and fertilizer to produce a profitable crop yield in a hail damaged field. Therefore, a possible increase in management costs needs to be considered in the decision to keep and harvest a hail damaged field. In addition, cotton yield losses caused by leaf damage due to hail storms are not accounted for in the current USDA and NCIS yield loss estimation procedures. Furthermore, differences in growth habits of cotton varieties (such as those with a bushy or cluster growth habit, showy or more closed bolls) may also play a role in the degree of crop yield loss due to a hail storm. The above procedures for estimating yield losses could be improved if there is more locally derived information on hail damage available.

There is no doubt that hail storms often force growers to make hard decisions, but a rule of thumb from the Mississippi State University Extension Service (2009) should help: "If you have enough cotton left to make the decision difficult, you probably have enough to keep".

Acknowledgements

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